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Mild heat stress and short water restriction treatment in lactating Alpine and Saanen goats

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ABSTRACT

Heat and water stress are rampant challenges in animal production as a result of climate change. Sixteen lactating goats of the Alpine and Saanen breeds were subjected to water restriction for 16 h on two consecutive days followed by rehydration, along with naturally rising temperature that culminated by the end of an experimental period of one week. Data were collected from the animals on four separate days representing their status under control conditions when temperature was still within their comfort zone, on the second day of the water restriction treatment, 24 h after rehydration and finally on the day when ambient temperature was above the normal average. Animals showed an increase in rectal temperature with time as ambient temperature increased. The heat stress was reflected by the decrease in pCO_2 and HCO_3 concentrations consistent with the onset of panting, while milk production was maintained but the concentration of major milk components decreased. Water stress, on the other hand, led to hemoconcentration with increased osmolality, Na^+, urea, glucose and albumin concentrations and an increase in milk lactose. The changes in blood parameters were reversed 24 h after rehydration but were slightly lower than normal, indicating the need for more than 24 h to re-adjust water balance in these lactating animals. Finally, the latency between first feeding and the following drinking event after return from milking showed that the shortest latency was under the water restriction treatment indicating thirst, in addition, a trend for shorter latency before drinking over the experimental period was observed in response to the rise in temperature. This experiment showed the capacity of these highly productive breeds to withstand mild water and heat stress. However, subtle changes in physiology and milk composition warrant further research into their effect on milk quality and animal welfare.

1. Introduction

Heat stress, often complicated by water scarcity, is reported to cause a wide range of effects on dairy goats from mild physiological disturbances to reduction in milk production and reproductive efficiency ending with serious welfare and health deterioration (Battini et al., 2016). Until recently, this environmental challenge was considered a concern for arid and semi-arid regions mainly; however, due to climate change, temperate areas, and their native livestock breeds, are now increasingly affected. Heat stress can induce a wide range of physiological responses starting with a decrease in feed intake to the activation of cooling mechanisms such as panting which in turn can lead to respiratory alkalosis (Barnes et al., 2004; Belhadj Slimen et al., 2016; Salama et al., 2014). At the same time, a reduction in milk production is often reported under heat stress with altered milk composition (Belhadj Slimen et al., 2016; Das et al., 2016; Jaber et al., 2013).

Water stress is another complicating condition that is commonly encountered when water resources are restricted such as in arid and semi-arid regions. However, adapted goat breeds have developed mechanisms to cope with this stress (Jaber et al., 2015; Kaliber et al., 2016). The common effects of water stress include a reduction in feed intake and hemoconcentration along with the activation of water saving mechanisms leading, among other physiological changes, to increased blood osmolality and reduction of urine output (Jaber et al., 2013). However, the effect of water stress on milk production and composition is variable depending on the breed and the severity of the treatment (Belhadj Slimen et al., 2016; Jaber et al., 2015).

Although goats in general are considered hardy animals, variability in breeds' resistance to certain environmental conditions is observed (Battini et al., 2016; Silanikove and Koluman, 2015). As noted above,

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Table 1
Timeline of experiment on mild heat stress and short water restriction treatment in lactating Alpine and Saanen goats.

Date Treatment	June 21 Control	June 22	June 23 Water restriction	June 24	June 25 24 hrs rehydration
Experimental setting	• Blood and milk sampled • Ad lib. water and feed • Feed and water intake recorded in the morning and evening • Mild temperature	• Water withheld after afternoon milking until next morning (16 hrs.) • Ad lib. feed	• Blood sampled in the morning at the end of water restriction and before feeding and watering • Water withheld after afternoon milking until next morning (16 hrs.) • Feed and water intake recorded in the morning and evening • Milk sampled	• Ad lib. water and feed.	• Blood and milk sampled • Ad lib. water and feed, after sample • Feed and water intake recorded in the morning and evening

Date Treatment	June 26-28	June 29 Heat stress
Experimental setting	Ad lib. water and feed	• Ad lib. water and feed. • Blood and milk sampled • Feed and water intake recorded in the morning and evening • High environmental temperature

highly productive temperate breeds, such as the Saanen and Alpine breeds, are now facing settings beyond their comfort zones, in their native regions, as well as in foreign countries where they are imported for their attractive productive traits. The literature on the adaptability of these breeds to heat and/or water stress is scarce (Meza-Herrera et al., 2006; Olsson and Dahlborn, 1989; Salama et al., 2014) thus warranting continued exploration of this topic.

The current experiment aimed to evaluate the response of Saanen and Alpine lactating does to a natural heat episode that occurred in France along with an imposed treatment of two consecutive days of 16-hour water restriction.

2. Material and methods

2.1. Animals and diet

This study was conducted, in June (Table 1), at the Experimental Farm of the research Unit Inra-AgroParisTech MoSAR (Thiverval-Grignon, France, 48°51′ N; 1°55′ E; 70 m above sea level). Eight Alpine and eight Saanen goats (160 DIM at the start of the experiment) were included. Half of them were in metabolic crates for continuous monitoring of eating and drinking behaviour. The animals were adapted to the experimental setting and procedures. They were given free access to feed and water. The feed consisted of a total mixed ration (TMR) offered twice daily after milking, in the proportion of two thirds at 4 p.m. and one third at 8 a.m., according to the milking intervals. The ingredients of the diet, on a dry matter basis, were dehydrated lucerne (30%), meadow hay (20%), pressed sugar beet pulp (30%) and compound concentrate feed (20%).

2.2. Experimental design and data collection

Temperature (T in °C) and humidity (H%) were measured in the experimental facility three times a day: 9 a.m., 1.30 pm and 5 pm (GMT + 2 h). The temperature-humidity index (THI) was calculated according to the following formula (Dikmen and Hansen, 2009; Mader et al., 2006):

THI = 0.81 T + (H/100) * (T - 14.4) + 46.4. During the experimental period, temperature was naturally rising, reaching exceptionally high degrees (27 °C, in the afternoon) for this area by the end of the period as compared to the average maximum temperature reported for that region which does not exceed 22 °C (Météo France, 2019).

Moreover, on June 22 and June 23, the animals were subjected to water restriction in the afternoon whereby water was withheld following the afternoon milking until the next morning (a total period of 16 hs per day). Accordingly, 4 days in June were selected to represent four different conditions that the animals have been exposed to: control (June 21), water restriction (June 23 following the first period of 16 h. water restriction), 24 h after rehydration (June 25), and heat stress (June 29).

Individual amounts of feed and water, offered and refusals, were weighed daily. Jugular blood samples were taken in the morning prior to offering feed and water. Anion Gap, pH, pCO_2, pO_2, $HCO3^-$, Na^+, Cl- and K^+ were immediately determined by a blood gas and mineral analyzer (ABL 77, Radiometer, Copenhagen Denmark). Plasma was collected and stored at −20 °C until assays for glucose, non-esterified fatty acids (NEFA), albumin, and urea using a Cobas Mira-Analyzer (Roche, Mannheim, Germany) with commercial kits for glucose (Glucoquant, Glucose/HK, Roche Diagnostic, Mannheim, Germany), NEFA (NEFA-HR(2), Wako, Chemical GmBH, Neuss, Germany), albumin (80002, Biolabo, 02160, Maizy, France) and urea (Urea/BUN, Roche Diagnostic, Mannheim, Germany). Osmolality was determined with a MARK3, Radiometer analytical S.A. osmometer (manufactured by FISKE® ASSOCIATES, Norwood, MA) by a method based on the depression in the critical freezing point. Daily milk samples were also taken and analysed for fat, protein and lactose contents.

This paper looks at the physiological effects of the different conditions that the animals were subjected to in addition to the changes in milk production and composition. Furthermore, drinking behaviour was also assessed, as reflected by the latency between first feeding and the following drinking event after return from milking.

2.3. Data analysis

The data were analysed by paired-t test using the IBM-SPSS Statistics 21 software. June 21 was used as the control for each animal and was compared separately to each of the subsequent days of the experiment. The difference between the two breeds for each parameter on the four experimental days was analysed by one way ANOVA. No major differences between the two breeds were found except for higher milk fat in the Alpine as compared to the Saanen breed. Furthermore, since they both showed similar trends in response to the treatments the results of both breeds were combined.

3. Results

3.1. THI, rectal temperature, feed and water intake and body weight

In the present study, the temperature and THI conditions (Table 2) steadily increased from June 21 to June 29, with the temperature reaching 27 °C in the afternoon and an average THI of 70.5. The calculated thermal heat index on June 23, 25 and 29 was significantly higher than on June 21, the control day. The percent humidity was not significantly different on any of the experimental days as compared to the control (data not shown).

The rectal temperature (Table 2) also increased in relation to the control day June 21.

Although there was no significant difference in feed intake (Table 2) between June 21 and June 29, feed intake was reduced on June 23, under water restriction, compared to June 21. However, normal feeding was restored within 24 h after rehydration (June 25). The total daily water intake (Table 2) was the highest on June 25, the day of rehydration, while the morning water intake was the highest on June 23, immediately following a 16 h water restriction period. Body weight was higher in all the experimental days as compared to the control with the highest weight registered under rehydration.

3.2. Physiological changes

The physiological changes under the four experimental conditions are presented in Tables 3 and 4. Concerning plasma parameters (Table 3), it is worth noting that blood glucose was significantly lower on June 29, when the ambient temperature was the highest, and significantly higher under water restriction (June 23), while NEFA and Beta-hydroxybutyrate (BHB) levels remained relatively stable, except for significantly higher BHB on June 23 under water restriction. Plasma urea, albumin and osmolality were significantly higher under water restriction than on the control day and osmolality was significantly lower on the day of rehydration (June 25).

The electrolytes Na^+ and Cl^- were higher under water restriction on June 23 than on the control day, in addition to slight but significantly higher Na^+ ion on June 29 under heat stress. In contrast the K^+ concentration was not modified throughout the experimental period.

The acid-base parameters in Table 4 show that the anion gap was higher, while the pCO_2, HCO_3 and base excess were lower on the respective experimental days as compared to the control day. The pO_2 levels did not show significant changes between the experimental days (data not shown). The pH was not modified throughout the experimental period.

3.3. Milk production and composition

Milk production and milk composition results are shown in Table 5. Milk production slightly fluctuated in response to water restriction, rehydration and heat stress, but none of the differences were significant. A trend towards the dilution of milk constituents was observed leading to significantly lower milk lactose, fat and protein on June 29. In contrast, milk lactose was significantly higher on June 23, under water restriction, than on the control day.

3.4. Drinking behaviour

Regarding drinking behaviour and water intake in the morning and the afternoon (Table 6), upon return from milking, the animals had the longest latency between the first feeding and starting to drink in the afternoon of the control day and the shortest delay in the morning following water restriction.

4. Discussion

4.1. THI, rectal temperature, feed and water intake and body weight

The temperature or THI comfort zones for Saanen and Alpine goats are not well established. For instance, on the one hand, Toussaint (1997) reported the maximum temperature limit to be 27 °C for indoor kept dairy goats, while Das et al. (2016) reported the comfort temperature zone to be between 16 °C and 25 °C, for dairy animals in general to maintain their physiological body temperature below 39.1 °C, with noted variations between species and breeds. On the other hand, Silanikove and Koluman (2015) defined the THI comfort zone based on its effect on milk production, noting that milk production in goats started to decline at THI > 80. Accordingly, the temperature and THI conditions seem to reach the limit of the animals' comfort zone on

Table 2
THI, rectal temperature, feed and water intake and body weight, of 16 lactating Saanen and Alpine goats subjected to water restriction, rehydration and heat stress.

Parameter	Control (June 21) ± SEM	Water restriction[a] (June 23) ± SEM	Rehydration[a] (June 25) ± SEM	Heat stress (June 29) ± SEM	Correlation coefficient with THI
Temperature-Humidity Index[b]	62.7 ± 1.56	68.1* ± 2.20	68.8* ± 2.02	70.5* ± 0.99	
Temperature (°C)	17.7 ± 1.16	21.8* ± 1.83	22.6* ± 1.85	24.2** ± 1.41	
Relative Humidity (%)	60 ± 3.1	58 ± 5.7	53 ± 6.4	48 ± 10.4	
Rectal temperature (°C)	38.54 ± 0.056	38.80*** ± 0.044	38.83*** ± 0.058	38.85*** ± 0.061	0.985*
Feed intake (Kg)	5.45 ± 0.129	5.00*** ± 0.134	5.40 ± 0.140	5.34 ± 0.145	−0.320
Water intake (L/24 h)	6.62 ± 0.253	6.41 ± 0.301	8.14*** ± 0.296	7.91** ± 0.316	0.631
Morning water intake (L)	2.44 ± 0.138	6.41*** ± 0.301	3.01** ± 0.142	2.86 ± 0.160	0.234
Body weight (Kg)	60.6 ± 1.82	62.0* ± 1.86	62.53** ± 1.99	62.04* ± 2.12	0.899

*,**,***indicate significance with $P < 0.05$, 0.01 and 0.001 respectively.

[a] Water removed after the afternoon milking until next morning for two consecutive days, data taken following the first restriction episode. Rehydration data taken 24 h after the end of water restriction treatment.

[b] The temperature-humidity index (THI) was calculated according to the formula of Mader et al. (2006): THI = 0.81 T + (H/100) * (T - 14.4) + 46.4.

Table 3
Plasma chemistry parameters in 16 lactating Saanen and Alpine goats subjected to water restriction, rehydration and heat stress.

Parameter	Control (June 21) ± SEM	Water restriction[a] (June 23) ± SEM	Rehydration[a] (June 25) ± SEM	Heat stress (June 29) ± SEM	Correlation coefficient with THI
Glucose (g/L)	0.583 ± 0.0054	0. 625* ± 0.0167	0.571 ± 0.0071	0.565* ± 0.0076	−0.159
NEFA (mmol/L)	137 ± 6.6	133 ± 4.8	125 ± 4.2	137 ± 3.8	−0.308
BHB (mg/L)	38 ± 2.28	41* ± 2.6	39 ± 2.2	40 ± 1.9	0.689
Urea (g/L)	0.256 ± 0.0171	0.331*** ± 0.0169	0.250 ± 0.0136	0.275 ± 0.0150	0.251
Albumin (g/L)	43.43 ± 0.371	46.04*** ± 0.523	42.77 ± 0.342	44.48 ± 0.695	0.266
Osmolality (mOsm/Kg)	294 ± 0.6	306*** ± 0.9	292* ± 0.5	294 ± 0.7	0.072

$^{*},^{**},^{***}$indicate significance with P < 0.05, 0.01 and 0.001 respectively.

[a] Water removed after the afternoon milking until next morning for two consecutive days (June 22 and 23). Blood was sampled at the end of the first water restriction period, before offering water and feed. Rehydration data taken 24 h after the end of water restriction treatment.

June 29. Literature, although limited, indicates wide differences between goat breeds' capacities to handle high temperatures, with temperate dairy breeds, such as the Alpine and Saanen, showing relatively more physiological and productive disturbances as compared to breeds native to hot regions (Das et al., 2016; Silanikove and Koluman, 2015). The rise in ambient temperature during the experimental period was reflected through the animals' increase in rectal temperature in all experimental days as opposed to the control one. However, the rectal temperature remained within the normal range for goats (Das et al., 2016).

Feed intake did not decrease with increasing ambient temperature in contrast to literature (Lu, 1989). However, the effect of water restriction in reducing feed intake is in agreement with previous research (Jaber et al., 2013). These results on feed intake indicate that the water restriction treatment probably imposed a stronger stress on the animals than the high ambient temperature. In fact, thirst as a form of stress, is also reflected through the morning water intake on June 23. The animals imbibed on that morning a quantity similar to a 24-hour consumption on normal days, and more than double the quantity drank in the morning of the control day. This behaviour is in accordance with previously reported research on water restriction in goats. In fact, goats seem to have the adaptive capacity to tolerate this rapid water replenishment without risking water toxicity due to the role of the rumen in retaining much of this water to be gradually released into the blood as discussed in Silanikove (1994). However, the changes in feed and water intake did not seem to reflect on body weight which remained higher on all experimental days as compared to the control. The highest weight registered after rehydration is probably a reflection of the large quantities of water drank in a relatively short period in order to compensate for previous water restriction regime.

4.2. Physiological changes

The changes in plasma parameters reflective of heat stress included the lower glucose concentration on June 29 which could be an indication of hemodilution as reported by Olsson and Dahlborn (1989). However, other blood parameters such as Na^+ and albumin have actually slightly increased which indicates that hemodilution is unlikely, in addition to the fact that water consumption was only slightly increased. Alternatively, the decrease in glucose could be related to rapid glucose consumption from the blood to meet the higher maintenance requirements usually associated with heat stress due to the onset of higher muscular activity for panting and related cooling mechanisms (Salama et al., 2014). Moreover, the relative stability of NEFA and BHB levels under heat stress are in agreement with the literature, as heat stress seems to actually hinder fat mobilization (Belhadj Slimen et al., 2016; Hamzaoui et al., 2015; Kargar et al., 2015), in addition to the fact that in this experiment, feed intake was not significantly altered under heat stress, thus the animals were probably not under energy deficit.

Other indices of the onset of heat stress on June 29 are the changes in acid-base parameters. Goats resort to panting as an important method for heat dissipation (Chedid et al., 2014). Eventually, sustained panting leads to the accelerated loss of CO_2 through the lungs, and consequently accelerated loss of HCO_3 from the blood, leading to respiratory alkalosis (Barnes et al., 2004). The current results show that although blood pH was maintained, there was in fact a gradual decrease in pCO_2 and HCO_3 concentration throughout the experimental period. Moreover, the results also show a decrease in base excess and an increase in anion gap. The decrease in base excess could be due to the increased excretion of HCO_3 through the kidneys which is thought to take place to alleviate respiratory alkalosis leading to compensatory metabolic acidosis. Beatty (2005), described this chain of events noting that in cattle, respiratory alkalosis is mostly experienced during the hottest parts of the day while compensatory metabolic acidosis is observed during the cooler periods. However, in the absence of more frequent measurements, the results of the current study warrant further investigation to understand the dynamics of acid-base regulation mechanisms and their interactions with heat stress and other possible

Table 4
Blood pH, gases and acid-base changes, in 16 lactating Saanen and Alpine goats subjected to water restriction, rehydration and heat stress.

Parameter	Control (June 21) ± SEM	Water restriction[a] (June 23) ± SEM	Rehydration[a] (June 25) ± SEM	Heat stress (June 29) ± SEM	Correlation coefficient with THI
pH	7.41 ± 0.008	7.41 ± 0.007	7.41 ± 0.009	7.42 ± 0.009	0.586
Na^+ (mmol/L)	142 ± 0.3	149*** ± 0.4	143 ± 0.3	143** ± 0.2	0.260
Cl^- (mmol/L)	109 ± 0.4	114*** ± 0.5	109 ± 0.4	108 ± 0.3	0.001
K^+ (mmol/L)	4.0 ± 0.11	4.2 ± 0.12	4.0 ± 0.13	3.9 ± 0.10	−0.139
Anion Gap (mmol/L)	9.0 ± 0.30	12.0*** ± 0.31	11.6*** ± 0.29	12.4*** ± 0.35	0.977*
pCO_2 (mmHg)	44.9 ± 2.95	42.9* ± 3.04	42.0* ± 3.67	41.1** ± 2.36	−0.982*
pO_2 (mmHg)	37.0 ± 5.73	38.1 ± 5.66	37.9 ± 3.39	36.4 ± 3.61	0.003
HCO_3 (mmoles/L)	27.5 ± 2.16	26.5* ± 1.78	25.8** ± 2.32	25.9* ± 1.99	−0.950
Base excess (mmol/L)	3.7 ± 2.36	2.7* ± 1.93	1.8** ± 2.60	1.9* ± 2.18	−0.937

[a]Blood was sampled in the morning before offering feed and water.
[b]Water removed after the afternoon milking until next morning for two consecutive days, blood was sampled at the end of the first water restriction period, before offering water and feed. Rehydration data taken 24 h after the end of water restriction treatment.
$^{*},^{**},^{***}$indicate significance with P < 0.05, 0.01 and 0.001 respectively.

Table 5
Milk production and composition of 16 lactating Saanen and Alpine goats subjected to water restriction, rehydration and heat stress.

Parameter	Control (June 21) ± SEM	Water restriction[a](June 23) ± SEM	Rehydration[a] (June 25) ± SEM	Heat stress (June 29) ± SEM	Correlation coefficient with THI
Milk production (L/d)	3.61 ± 0.119	3.57 ± 0.110	3.73 ± 0.107	3.69 ± 0.110	0.495
Milk fat (g/kg)	33.1 ± 1.07	32.9 ± 1.06	32.3 ± 0.88	30.4*** ± 0.85	−0.738
Milk protein (g/kg)	31.8 ± 0.55	31.5* ± 0.55	31.6* ± 0.51	31.3*** ± 0.51	−0.910
Lactose (g/kg)	43.8 ± 0.34	44.7*** ± 0.38	43.4* ± 0.34	43.2** ± 0.33	−0.260

*,**,***indicate significance with P < 0.05, 0.01 and 0.001 respectively.
[a] Water removed after the afternoon milking until next morning for two consecutive days, data taken during the second day of water restriction. Rehydration data taken 24 h after the end of water restriction treatment.

contributing factors such as water or feed intake.

Previous literature reports mixed findings regarding the changes in glucose concentration during water stress (Jaber et al., 2013). In the current experiment, the higher glucose concentration could be a reflection of hemoconcentration due to a decrease in blood volume leading to the concentration of most blood constituents (Igbokwe, 1993). Surprisingly, the NEFA concentration was not affected by water restriction, in contrast to previous literature that reported an increase (Jaber et al., 2013). However, BHB was increased under water restriction, which could reflect fat mobilization in response to the decrease in feed intake (Salama et al., 2014). The apparent contradiction could be related to the delicate hormonal control of water and energy balance. Water stress can alter insulin and leptin levels (Belhadj Slimen et al., 2016), thus altering the rates of energy metabolic activities which reflect on blood metabolites. Further studies to elucidate the hormonal changes and related metabolic mechanisms are warranted to understand these findings. Hemoconcentration was further reflected by the higher concentration of albumin which is an important protein for body osmoregulation (Igbokwe, 1993). In addition, the increases in urea, Na^+ and osmolality are consistently reported under dehydration conditions as a reflection of the kidney function which will increase Na^+ and urea reabsorption as part of the mechanism activated for water reabsorption and conservation (Silanikove, 1994). Moreover, following rehydration on June 25, the animals seem to resort to water overconsumption, which is reflected in what appears to be a slight dilution of the blood. Osmolality was significantly decreased in addition to the relatively lower concentrations of NEFA, urea and albumin. This result shows that although the goats could handle the large water intake in a short period following rehydration, they probably need more than 24 h to restore normal blood composition. Olsson and Dahlborn (1989) working on heat and water stress in lactating goats, noted that they seem to have lower control over water balance than non-lactating counterparts, this may be the reason why the animals needed more than 24 h for restoring blood composition to normal.

4.3. Milk production and composition

Milk production in the Saanen and Alpine goats seemed to be maintained under the experimental conditions. In contrast, water restriction and heat stress were reported to decrease production in previous literature (Belhadj Slimen et al., 2016; Das et al., 2016). However, decrease in production is dependent on the breed, the level of milk production and the level of stress that is applied, which in this case seems to be relatively mild, thus causing little effect. Furthermore, Salama et al. (2014) suggested that the decrease in milk production of goats under heat stress could be entirely attributed to the reduction in feed intake, and since feed intake was maintained in our experiment, this could be the reason for the maintained milk production.

The changes in milk composition indicate a tendency towards dilution of milk components over the experimental period with increasing THI. This result is in agreement with previous reports which show the negative effect of heat stress on these milk parameters in goats (Das et al., 2016; Salama et al., 2014), although others have found no effect of heat stress on milk parameters in Egyptian baladi goats (El-Tarabany et al., 2017). On the one hand, the decrease is most noticeable in milk fat. Working with heat stressed cows, Kargar et al. (2015) observed that milk fat is the most affected component under heat stress since it is the most energy demanding at the time when the animal's maintenance requirements increase in order to cope with the heat stress. On the other hand, water restriction led to an increase in milk lactose, a result that is in agreement with previous research (Dahlborn, 1987; Hossaini-Hilali et al., 1994) since blood osmolality increased and milk is always isosmotic to blood with lactose being the major osmotic component in milk. These changes, while small, may have an impact on overall milk quality (Bernabucci et al., 2013) and on milk evaluation and processing into valuable dairy products such as cheese (Cowley et al., 2015; Hamzaoui et al., 2013).

4.4. Drinking behaviour

We speculate that most of the animals were motivated to eat before drinking. Research on drinking patterns in goats is scarce (Rossi and Scharrer, 1992, 1998, 1999a, 1999b). Rossi et al. (1999a) suggested that most of the drinking in pigmy goats was associated with meals, especially during daytime, and that this association between feed intake and water intake seems to be controlled by Histamine H1 receptors (Rossi el al., 1999b). Al-Ramamneh et al. (2012) noted that water restriction to 3 h per day or 6 h every two days caused a significant increase in the amount of water drunk per bout (g/kg BM0.75/bout), in the drinking duration (min/h) and in the drinking bouts (n/h). Previous reports on dairy cows, indicate that eating is often triggered upon return from milking or when fresh feed is offered (DeVries et al., 2005). In

Table 6
The latency between first feeding and the following drinking event after morning and afternoon milking, in 8 lactating Saanen and Alpine goats subjected to water restriction, rehydration and heat stress.

Parameter	Control (June 21) ± SEM	Water restriction[a] (June 23) ± SEM	Rehydration[a] (June 25) ± SEM	Heat stress (June 29) ± SEM	Correlation coefficient with THI
Latency before start of drinking (minutes:seconds)					
Morning	32:15 ± 3:19	17:09* ± 5:06	31:15 ± 2:33	27:31 ± 4:02	−0.349
Afternoon	33:32 ± 2:33	Water removed	26:30* ± 3:09	21:31** ± 2:41	−0.976

*,**,***indicate significance with P < 0.05, 0.01 and 0.001 respectively.
[a] Water removed after the afternoon milking until next morning for two consecutive days, data taken during the second day of water restriction. Rehydration data taken 24 h after the end of water restriction treatment.

the current experiment, feed was replenished during milking, which may explain the animals' tendency to eat right after returning to their stalls. Over the experimental period, the animals tended to show shorter latencies before drinking as compared to the control day, especially in the evening. This could be related to the increase in ambient temperature. Heat stress is often associated with drinking, including overdrinking in some cases (Olsson et al., 1995). The water stressed animals, on the morning of June 23, had a particularly short latency before drinking as compared to the control and other days, indicating their expected thirst. Daily ingestion and drinking patterns warrant further investigation as they may provide important clues on the critical periods of heat and thirst stress perception by the animals and thus open a possible way for appropriate adaptation in animal management.

5. Conclusion

In conclusion, this experiment highlighted the effects of mild heat and water stress on high producing Saanen and Alpine goats raised under temperate environment. The results indicate that subtle physiological changes take place under mild heat stress with possible implication on production particularly with regard to the decrease in the concentration of the major milk components. Moreover, short water restriction seemed to induce changes in blood parameters reflective of hemoconcentration and water conservation mechanisms. These effects tended to be reversed upon rehydration, but return to normal values seemed to require more than 24 h. In conclusion, although the animals were able to cope with mild water and heat stress, the physiological and milk composition changes warrant further research into their effect on animal welfare and milk quality.

Ethics

The present study was carried out according to French legislation on animal experimentation in line with the European Convention for the Protection of Vertebrates used for Experimental and other Scientific Purposes (European Directive 86/609). The scientist in charge of the experiments was licensed to perform experiments on animals and the staff who applied the experimental procedures had attended a special course approved by the French Ministry of Agriculture.

Authors' declaration

The authors declare that they all approve of this article which is their original work and that it has never been published nor is it considered for publication elsewhere.

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Conflicts of interest

The authors declare that there is no conflict of interest in relation to this article.

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